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HOME RANGE AND HABITAT USE BY GREAT HORNED OWLS (*BUBO VIRGINIANUS*) IN SOUTHERN CALIFORNIA

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ABSTRACT.—Great Horned Owls (*Bubo virginianus*) are a common, widespread species that can be found in a variety of habitats across most of North America, but little is known about their space and habitat requirements. Using radiotelemetry, location data were collected on nine male and five female Great Horned Owls to determine home range and habitat use in southern California. Owls were tracked between January 1997 and September 1998 for periods ranging from 5–17 mo. Seven owls were also followed during 13 all-night observation periods. The mean 95% adaptive kernel home-range size for females was 180 ha (range = 88–282, SE = 36) and that for males was 425 ha (range = 147–1115 ha, SE = 105). Core areas estimated by the 50% adaptive kernel averaged 27 ha (range = 7–44, SE = 7) for females and 61 ha (range = 15–187, SE = 18) for males. Owls were located in areas with varying degrees of human disturbance ranging from almost entirely urban to native oak (*Quercus agrifolia*) woodland. Oak/sycamore (*Quercus agrifolia/Platanus racemosa*) woodland and ruderal grassland (*Bromus* spp., *Avena* spp., and various other non-native invasives), were used more often than expected based on availability, but we found no correlation between home-range size and any single habitat type or habitat groups.

KEY WORDS: *Great Horned Owl*; Bubo virginianus; *home range*; *habitat use*; *southern California.*

ÁMBITO DE HOGAR Y USO DE HÁBITAT DE *BUBO VIRGINIANUS* EN EL SUR DE CALIFORNIA

RESUMEN.—*Bubo virginianus* es una especie común y ampliamente distribuida que puede ser encontrada en una gran variedad de hábitats a través de gran parte de América del Norte. Sin embargo, se sabe poco sobre sus requerimientos de espacio y hábitat. Se recolectaron datos de localización de nueve machos y cinco hembras de *B. virginianus* utilizando radio-telemetría, con el fin de determinar el ámbito de hogar y la utilización del hábitat de esta especie en el sur de California. Los búhos fueron seguidos entre enero de 1997 y septiembre de 1998 durante periodos que variaron entre 5–17 meses. Siete búhos también fueron seguidos durante 13 periodos de observación que duraron toda la noche. El tamaño promedio del ámbito de hogar identificado por el método de kernel adaptativo del 95% fue de 180 ha para las hembras (rango = 88–282, SE = 36) y de 425 ha para los machos (rango = 147–1115 ha, SE = 105). Las áreas núcleo estimadas por el kernel adaptativo del 50% fueron en promedio de 27 ha para las hembras (rango = 7–44, SE = 7) y de 61 ha para los machos (rango = 15–187, SE = 18). Los búhos se localizaron en áreas con distintos grados de perturbación humana, variando desde áreas totalmente urbanas hasta bosques nativos de *Quercus agrifolia*. Los bosques de *Q. agrifolia* y *Platanus racemosa* y las praderas ruderales con *Bromus* spp., *Avena* spp. y varias otras especies invasivas no nativas fueron utilizadas con mayor frecuencia de lo esperado según la disponibilidad de estos hábitats, pero no encontramos una correlación entre el tamaño del ámbito de hogar y un hábitat en particular o grupos de hábitats.

[Traducción del equipo editorial]

The Great Horned Owl (*Bubo virginianus*) is one of the most widespread birds of prey in the Americas (Houston et al. 1998). They are able to populate a wide range of habitats because they are generalist predators with one of the most diverse prey profiles of all North American raptors and can use a diverse range of nest sites (Bent 1938, Houston et al. 1998). In California, Great Horned Owls nest from sea level to at least 2500 m in elevation within a diverse range of both natural and human altered habitats and play an important role as a top predator in southern California's wildlife communities.

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Although Great Horned Owls are in little danger of vanishing from southern California, diverse native wildlife communities are threatened by rampant urban development. In general, conservation efforts in southern California have focused on single-species management of state and federally listed threatened and endangered species. An alternative approach is to focus conservation efforts on upper-trophic-level predators, such as large raptors, whose spatial and ecological requirements are likely to encompass those of many other species (Bednarz et al. 1990, Bloom et al. 1993). Furthermore, top-level predators play important ecological roles in maintaining biological diversity in human-altered landscapes by keeping mesopredator numbers in check (Soulé et al. 1988, Litvaitis and Villafuerte 1995, Crooks and Soulé 1999).

Great Horned Owls are of particular interest because they are one of the largest raptors in southern California, are likely to have large space requirements, and can adapt to and expand into areas altered or disturbed by humans. To our knowledge no quantitative information has been published on home-range size, habitat composition, and response of Great Horned Owls to land development in southern California.

STUDY AREA

The study area consisted of urbanized and "natural" areas of coastal foothills extending from Rancho Mission Viejo in the south, north to Huntington Beach in Orange County, California. Topography consisted of low elevation rolling hills and plains with seasonal streams and small rivers bisecting the landscape. We studied nesting pairs of Great Horned Owls in the cities of Huntington Beach, Lake Forest, Irvine, and Mission Viejo, as well as the more natural area of Rancho Mission Viejo (20 km east of Mission Viejo) and Ronald W. Caspers Regional Park. Elevation varied between 30–300 m above sea level.

Principal land uses in urban areas included city and regional parks, agriculture, housing, and industry. Land uses on Rancho Mission Viejo were cattle ranching and agriculture, but the area also contained large tracts of native vegetation communities. Permanent or intermittent water sources within owl home ranges included streams, channelized waterways, and artificial ponds. The region's climate is Mediterranean, typically arid with most rain occurring in February.

METHODS

Great Horned Owls were captured using bal-chatri traps (Berger and Mueller 1959, Bloom 1987) baited with live mice (*Mus musculus*), or with a dho-gaza trap using a live Great Horned Owl as a lure (Hamerstrom 1963, Bloom 1987, Bloom et al. 1992). Gender was determined by the presence or absence of a brood patch, by body size and mass, and age (i.e., hatch year, second year, and after hatch year) was determined by molt characteristics. Each owl was banded with a U.S. Geological Survey aluminum band and equipped with a radiotransmitter (Communications Specialists, Orange, CA U.S.A.) in a backpack configuration, fitting the radio between the wings with Teflon straps joining at the breast (Dunstan 1972). The combined mass of the transmitter and harness (28 g) was less than 3% of the mean body mass of the owls. Transmitters had an estimated battery life of 2 yr and a range of ca. 3 km.

Radiotagged owls were relocated using a hand-held radio receiver with a three-element yagi antenna. After a bearing was obtained, a precise location was ascertained by a visual sighting 44% of the time. Street lamps and urban glow often facilitated the sightings of owls. Movements were detected visually or by a change in radio signal strength, usually followed by a change in signal direction.

When an owl could not be located visually, locations were determined by triangulation. At least three compass bearings were taken sequentially within 15 min, usually at a distance of <150 m, and care was taken to minimize disturbance. We were often able to encircle an owl's position, and thus, could reliably infer the owl's location. A location determined by triangulation was used only if the resulting error polygon was <2 ha. Owl locations were plotted on a U.S. Geological Survey 7.5-min quadrangle map or on a road map.

Owls were located at all hours between sunset and sunrise and were followed through the battery life of the transmitter or the termination of the study (September 1998). Each owl was located ca. once per week and was tracked for up to 5 hr after initial detection. Additionally, six owls were tracked continuously throughout two entire nights and one owl was tracked a single night.

Spatial autocorrelation results from sampling stationary animals at short, regularly spaced time intervals, and Great Horned Owls often remain on a single perch for many hours. In order to reduce the degree of autocorrelation in our data set, yet maintain an adequate sample size, we recorded owl successive locations only when a perch change occurred. Also, we removed from the analysis all point locations recorded within 30 min of each other. Because location points were not collected at regularly spaced time intervals, "time to independence" of successive location points (Swihart and Slade 1985) was not applicable. The same locations were used for both home-range estimation and habitat-use analysis.

We digitized location points using Geographic Information System (GIS) software (ESRI 1995). The adaptive kernel (AK) estimate of home-range size (Worton 1989) was calculated for each owl using the program CALHOME (Kie et al. 1994). The AK method is less biased by the scale or grid density and can produce more consistent results than many other home-range estimators (Kie et al. 1994, Worton 1995, Seaman and Powell 1996, Hansteen et al. 1997, Lawson and Rodgers 1997). The grid cell option for the AK was set at a density of 50 × 50 cells for all home-range estimations.

We used the 95% AK utilization contours to delineate home-range boundaries for each owl, but if a location was used only once and it increased the home-range size by >10%, we removed it from our calculation (Bloom

1989). We used CALHOME's estimated optimum bandwidth (smoothing parameter; Worton 1989) for each data set. For comparison with other studies the 100% minimum convex polygon (MCP; Mohr 1947) and the 95% harmonic mean (HM; Dixon and Chapman 1980) estimations were also calculated. We chose the 50% AK contour to represent core areas within the home range of each owl.

We categorized habitat as belonging to one of eight common vegetation communities of southern California: oak woodland (*Quercus* spp.), oak/sycamore woodland (*Quercus agrifolia/Platanus racemosa*), exotic woodland, coastal sage scrub, riparian scrub, agriculture, urban, and ruderal grassland. We based these habitat types on dominant vegetation and physiognomic features. All areas included roads, utility poles, and buildings to varying degrees.

Oak woodland was characterized by a closed or nearly closed canopy of coast live oak (*Quercus agrifolia*), with a relatively open understory, was relatively rare, found primarily in linear groves along the bottoms and on north facing canyon slopes. Oak/sycamore woodland was more closely associated with intermittent or perennial streams. This habitat contained ca. equal proportions of coast live oak and sycamore (*Platanus racemosa*) 10–20 m in height with a broken canopy. We classified various nonnative woodland habitats as exotic woodland. Included were parks and golf courses, which contained pine (*Pinus* spp.) and gum (*Eucalyptus* spp.) stands with an open understory of turf grass. Gum trees were common in urban and ranch areas and were included in this habitat type when stands exceeded ca. 1 ha.

Of the non-woodland habitat, coastal sage scrub was found on exposed hillsides with a diverse array of drought tolerant shrubs predominating. Dominant shrubs included lemonade berry (*Rhus integrifolia*), laurel sumac (*Malosma laurina*), and California sagebrush (*Artemisia californica*). Riparian scrub consisted of young and mature willow (*Salix* spp.), mulefat (*Baccharis salicifolia*), and other shrubs found along open-stream washes and creeks. Agricultural areas included citrus, corn, strawberry, and potted-ornamental plant production often with open patches of exposed soil. Urban habitats consisted of housing, industrial parks and buildings, small areas of associated landscaped vegetation, pavement, and the surrounding road system.

Ruderal grassland was characterized by large open fields of nonnative grasses (*Bromus* spp., *Avena* spp., *Hordeum* spp.), black mustard (*Brassica nigra*), and other weedy plant species occasionally interspersed with trees or small patches of coastal sage scrub. Presence of these areas was mainly a result of cattle ranching and the invasion of nonnative weeds into disturbed native habitats. These same weedy species were found to some extent in all of the habitats. Native grasses, such as perennial needle grass (*Nassella pulchra*), were present but were mainly restricted to small patches in the coastal sage scrub community.

Habiat boundaries were digitized using GIS software (ESRI 1995). Total area of each habitat type within an owl's home range was determined by clipping the habitat polygon layer with the home-range boundary layer. The percentage of owl locations within each habitat was compared with the percent of each available habitat within the owl's home range. Often an owl was found on an ecotone between two habitat types. In these instances one-half of a location was recorded for each habitat.

We applied the two-tailed Mann-Whitney *U*-test to compare male and female home-range size and statistics are presented with standard error (SE). We used the Friedman method (Friedman 1937, Alldredge and Ratti 1986) to test if Great Horned Owls used certain habitats proportionately more than the availability of that habitat within their home range. We analyzed the relationship between home-range size and percent of each habitat type found within an owl's home range using the Spearman's rank correlation (r_s).

RESULTS

Five female and 10 male territorial-adult Great Horned Owls were fitted with radio transmitters and tracked during time periods ranging from 5–17 mo (Table 1). Nine owls were caught near their occupied nests and six were caught outside the breeding season. All tracking periods were between January 1997 and September 1998. The nesting success of one male was unknown, but all other owls fledged young successfully during at least one breeding season.

We collected 1069 location points for 15 owls. Area-observation curves (Odum and Kuenzler 1955) using both 95% AK and 100% MCP were produced for each owl to ensure that enough location points were obtained to describe the home ranges adequately. The area estimated by both the AK and MCP approached an asymptote for most owls after ca. 50 ± 4.5 locations were obtained.

Area-observation curves for four owls indicated that enough location points might not have been obtained to describe these home ranges adequately. The signal for one owl was lost early in the study and the individual was removed from the analysis (MO2; Table 1). Females F06 and F14 were tracked for ca. 6 mo starting from the late nestling stage through the fledging stage of their young. These locations may not be representative of a full year's movements, but F14 had the largest home range of all females and her home-range size was unlikely underestimated. Because F14 and F06 were tracked over the same time period, both were included in home-range comparisons. The area-observation curves for M18 were level from 10–35 location points, but toward the end of the study its home-range size more than doubled when it started using a new area outside its previous range. We used the home-range estimated before it moved for home-range analysis.

Table 1. Home-range and core-area sizes (ha) for Great Horned Owls in southern California radiotracked between January 1997 and September 1998. Home ranges determined by adaptive kernel (AK), minimum convex polygon (MCP), and harmonic mean (HM) methods.

OWL ID[a]	MONTHS TRACKED	NUMBER OF LOCATIONS	AK 95%	AK 50%	PERCENT CORE AREA	MCP 100%	HM 95%
F03[1]	17	83	133	16	12	123	140
F05[2]	11	76	152	31	20	146	130
F06[3]	5.5	51	88	7	8	80	74
F08	9	68	244	44	18	212	275
F14[4]	5	61	282	37	13	256	271
Female Means	10	68	180	27	14	163	178
M00	15	89	659	79	12	510	602
M01	13	80	1115	187	17	1066	1195
M02[1c]	3.5	16	285	46	16	160	145
M04	17	97	409	57	14	465	451
M07[3]	15	97	147	15	10	163	171
M09	14	98	211	38	18	260	247
M12[4]	6	70	589	96	16	484	698
M15[2]	6	68	179	40	22	166	159
M17	6	68	257	21	8	188	382
M18	6	47	257	18	7	172	237
Male Means	11	79	425	61	14	386	460

[a] Superscript number indicates pairs and F = female and M = male.
[b] Percent core area = (AK 50%)/(AK 95%) × 100.
[c] Removed from analysis and calculation of means.

Female Home-Range Size. The 95% AK home range of five female Great Horned Owls averaged 180 ± 36 ha (Table 1). The largest female home range (282 ha) was more than three times larger than the smallest (88 ha). Both of these females fledged young successfully and were tracked during ca. the same 5-mo period.

Male Home-Range Size. The 95% AK home range of nine male Great Horned Owls averaged 425 ± 105 ha. The largest male home range (1115 ha) was more than seven times larger than the smallest male home range (147 ha). Both of these owls were tracked for 15 mo and nested.

There was high variation among home-range sizes. Although home-range size of males averaged more than twice that of females, it was not significantly different (U = 36, P = 0.04). The discrepancy in mean home range size between the sexes was due primarily to the large size of M01's home range (1115 ha), which was 1.7 times larger than the next largest male home range (659 ha). When we compared home ranges of four mated pairs the male's home range encompassed most of the female's and was, on average, 36% larger.

Core Areas. Core areas estimated by the 50% AK averaged 27 ± 7 ha for females and 61 ± 18 ha for males. The percentage of the core area averaged 14% ± 1.3% of the total home range and was nearly identical for both males and females. Core areas were centered on a few frequently-used perches at which the owls could be regularly found throughout the study.

Nightly Home Range. Three males and three females were tracked continuously over two entire nights and one male was tracked for one entire night. Owls often returned to the same perch after short visits to nearby perches and many were highly sedentary. Mean number of perch changes from the day roost through the night for all owls was 10.0 ± 1.3 (Table 2). The mean 95% AK area used nightly was 46.2 ± 9.8 ha. This averaged 21.3% (range 0.9–39 ha) of the entire home-range size. There was no difference between the size of home range used (U = 19, P = 0.47) or the percentage of the home range used nightly (U = 25, P = 0.15) between males and females.

Habitat Use. Not all habitat types were found in each owl's home range and owls in the most urbanized areas had the fewest habitat types within their home range. We found no correlation between home-range size and any of the habitat types ($r_s \leq 0.4$, N = 14, $P > 0.05$).

Table 2. Nightly 95% adaptive kernel (AK) home range (ha) and perch changes by seven Great Horned Owls in southern California radiotracked continuously from sunset to sunrise.

OWL ID	1998 DATE	PERCH CHANGES	NIGHTLY HOME RANGE (ha)	PERCENT OF TOTAL HOME RANGE
F05	Sept 4	7	53	34.9
	Sept 10	4	53	34.9
F06	June 19	12	34	38.6
	July 20	17	12	13.6
F14	July 23	9	33	5.6
	Aug 17	10	134	33.3
M04	Feb 22	15	49	12.0
M12	July 7	5	—[a]	—[a]
	Aug 17	10	37	6.3
M15	Aug 28	13	66	36.9
	Sept 4	5	61	34.1
M17	Aug 14	6	2.3	0.9
	Sept 7	17	20	7.8
Means		10	46	22

[a] Only two perches close in proximity were used, hence home range could not be estimated.

Relative to availability, oak/sycamore and ruderal grassland were used by Great Horned Owls to a greater extent than agriculture, exotic forest, coastal sage scrub, and urban habitats ($P = 0.03$). Ruderal grassland was found within each owl's home range, but oak/sycamore woodland was absent from home ranges of five of the 14 owls (those in mostly urban areas).

DISCUSSION

Few studies have attempted to determine home-range size and habitat use of Great Horned Owls in North America. Early estimates of home-range size relied on resighting unmarked individuals in Wyoming and Utah and ranged between 70–300 ha (Craighead and Craighead 1956, Smith 1969). Home-range estimates (cumulative grid square) of

Table 3. Percent of Great Horned Owl locations within each habitat type (left)/percent of habitat type within respective home range (right).

OWL ID	OAK/ SYCAMORE	OAK	EXOTIC FOREST	SAGE SCRUB	RIPARIAN SCRUB	RUDERAL GRASSLAND	AGRICULTURE	URBAN
M00	47/12	0/2	—[a]	51/81	1/3	1/0	0/1	—[a]
M01	31/13	—[a]	3/4	26/17	—[a]	24/20	—[a]	16/45
F03	—[a]	—	31/35	—[a]	—	62/47	—	7/18
M04	17/8	6/8	—	38/25	6/3	6/2	—	27/54
F05	1/3	31/16	1/1	19/38	25/16	20/20	3/4	—
M15	0/4	20/14	1/3	34/36	26/16	17/21	2/6	—
F06	22/5	—	—	3/9	—	16/21	0/7	59/58
M07	13/5	—	—	4/14	—	19/21	2/4	62/56
F08	32/30	—	—	10/14	—	28/20	—	30/35
M09	—	—	—	—	8/9	13/7	—	79/84
M12	—	—	—	—	—	30/8	26/9	44/83
F14	—	—	—	—	—	13/1	14/13	73/86
M17	—	—	—	—	—	67/40	10/14	23/46
M18	1/2	—	6/5	4/9	—	58/44	31/40	—

[a] Habitat not found in home range.

one radio-tagged female and two radio-tagged males in Minnesota were 71, 148, and 495 ha respectively (Fuller 1979). In the Yukon Territory, home-range size of 16 pairs of owls observed while hooting ranged from 230–883 ha (ξ = 483 ± 40 ha; Rohner 1997). Home-range sizes in this study were consistent with these observations (ξ = 337 ± 75 ha, range = 88–1115).

As with studies of many other raptors, home-range size of females was smaller on average than that of males (Brown and Amadon 1968, Newton 1979, Bloom et al. 1993); perhaps, due to the female's responsibilities at the nest during the early and middle parts of nesting period. During incubation and brooding (January–March), three female owls with radiotransmitters rarely left their nests. Females found away from their nests when young were present were typically within 0.5 km of the nest structure. Male home-range sizes were consistently larger than female home ranges from nestling through the late post-fledging stages of breeding. Our sample size was too small to make seasonal home-range comparisons.

Home-range sizes of both male and female Great Horned Owls varied substantially among individuals. The largest home range (1115 ha) for males was 7.5 times larger than the smallest (147 ha) and 12.5 times larger than the smallest female home range (88 ha). This was not caused by differences in tracking periods as the largest and smallest home ranges for both males and females were from individuals tracked over ca. the same time periods.

Rohner and Krebs (1998) found that home-range size of Great Horned Owls was related to owl density rather than to prey availability. Owl density was not measured here, but there was no home range overlap between three territorial males that held territories adjacent to one another. Also, vocal exchanges between radio-tagged owls and untagged adjacent owls were infrequent, suggesting relatively low densities of Great Horned Owls in the study area.

Variation in home-range size may be due to such factors as prey abundance and availability across each owl's territory. Although some studies have shown a correlation between home-range size and prey availability or preferred habitat (e.g., Carey et al. 1990, Bloom et al. 1993, Babcock 1995, Zabel et al. 1995, Mazur et al. 1998), we found no correlation between any single-habitat type or habitat groups and home-range size.

Owls were located more often in oak/sycamore woodland and ruderal grassland when available. Both of these habitats were ideally suited to a perch-and-wait predator, such as the Great Horned Owl, having numerous elevated perches with sparse or open ground cover. The lack of correlation between home-range size and habitat type may be due to differential prey availability within habitat classifications. Habitat types under the same classification were not homogeneous throughout the study area and prey availability may have varied between sites. Although prey abundance was not measured in this study, Great Horned Owls likely respond to prey availability by ranging more widely where availability is low (Newton 1979).

During continuous all-night observations owls used a mean of 21% of their home range, but percent of total home-range use varied considerably (Table 2). Interestingly, one owl moved so little that the 95% AK home range could not be estimated and four owls used less than 8% of their total home range. During the fall, one female was observed on the same perch for eight continuous hours and only changed perches four times the entire night; there were no observed interactions with its mate.

Anecdotal evidence suggests that hunting success may play a role in activity level. On several occasions owls were observed overlooking numerous cottontail rabbits with no apparent interest. Owls observed making unsuccessful attempts at prey capture usually continued to be active.

Many factors may affect the space use by Great Horned Owls in southern California. In general, home-range sizes of birds of prey are strongly influenced by the interactions of habitat availability, prey abundance and distribution, energetics, and territoriality (Newton 1979, Forsman et al. 1984, Bloom et al. 1993, Babcock 1995). Some of these factors may become more complex in areas of intense land development, where space, prey abundance, and prey vulnerability change rapidly.

Great Horned Owls are an important upper-trophic level component of southern California's wildlife communities with a wide prey base. These prey include mesopredators, such as the striped skunk (*Mephitis mephitis*), California ground squirrel (*Spermophilus beecheyi*; P. Bloom unpubl. data) and possibly young house cats (*Felis domesticus*). An increase in mesopredator numbers due to the exclusion of top predators has been shown to be detrimental to avian populations in fragmented habitats of southern California and elsewhere (Soulé et al. 1988, Litvaitis and Villafuerte 1995, Rodgers and Caro 1998, Crooks and Soulé 1999). Maintaining and managing Great Horned Owls, particularly on the interface between urban and natural areas, may act to reduce the threat of mesopredator release and maintain greater biological diversity. Paradoxically, Great Horned Owls are known to prey upon White-tailed Kites (*Elanus leucurus*; J. Bennett and P. Bloom pers. obs.) and Peregrine Falcons (*Falco peregrinus*; Walton and Thelander 1988), and they pose a threat to other sensitive species in the region.

Although Great Horned Owls are successful in some human-altered landscapes, they are typically absent from most urban and suburban areas (P. Bloom unpubl. data). As development continues to remove natural wildlife habitat, land-use planners and wildlife biologists need information on what is required to sustain healthy wildlife communities in the surrounding landscape. Urban and rural parks and preserves can encourage the presence of Great Horned Owls if they are provided an area of at least 425 ha in size with appropriate habitats to sustain an adequate prey base.

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